



# The Effect of Tungsten and Niobium on the Stress Relaxation Rates of Disk Alloy CH98

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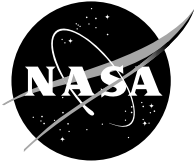
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## Document History

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# THE EFFECT OF TUNGSTEN AND NIOBIUM ADDITIONS ON THE STRESS RELAXATION RATES OF DISK ALLOY CH98

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## INTRODUCTION

Gas turbine engines for future subsonic transports will probably have higher pressure ratios which will require nickel-base superalloy disks with 1300°F to 1400°F temperature capability. Several advanced disk alloys are being developed to fill this need. One of these, CH98, is a promising candidate for gas turbine engines and is being studied in NASA's AST Program. For large disks, residual stresses generated during quenching from solution heat treatment are often reduced by a stabilization heat treatment, in which the disk is heated to 1500°F to 1600°F for several hours followed by a static air cool. The reduction in residual stress levels lessens distortion during machining of disks. However, previous work on CH98 has indicated that stabilization treatments decrease creep capability (Ref. 1). Additions of the refractory elements tungsten and niobium improve tensile and creep properties after stabilization, while maintaining good crack growth resistance at elevated temperatures (Ref. 2). As the additions of refractory elements increase creep capability, they might also effect stress relaxation rates and therefore the reduction in residual stress levels obtained for a given stabilization treatment. To answer this question, the stress relaxation rates of CH98 with and without tungsten and niobium additions are compared in this paper for temperatures and times generally employed in stabilization treatments on modern disk alloys.

## MATERIAL & TEST PROCEDURES

CH98 is a nickel-base superalloy with a gamma prime content of about 60%. The compositions of experimental heats of CH98 and CH98 with tungsten and niobium additions, hereafter CH98+WNb, are shown in Table 1. As previously stated, this level of alloying addition for these two elements significantly improves creep and tensile capability. Both alloys were produced from argon atomized powder which was compacted at 2000°F followed by extrusion at 2000°F with an 8:1 reduction ratio. Specimen blanks were cut from the extrusions (longitudinal orientation) and HIPed at 2225°F/30KSI/3HR to achieve an ASTM 6-8 grain size without introducing excessive porosity. These blanks were then solution heat treated at 2200°F/1HR and air cooled producing an initial cooling rate of 200°F/MIN. Test specimens, with a cylindrical gage section, were machined from the as-solutioned blanks using a low stress grinding operation per the configuration shown in Figure 1.

Stress relaxation tests were run on the test specimens at 1400, 1500, 1550, and 1600°F using a 20KIP MTS servohydraulic test system equipped with an electric furnace and an axial extensometer. In order to achieve thermal equilibrium, each specimen was held at test temperature for 30 minutes (zero load) prior to the onset of testing. At this point, the

test rig was switched to strain control and the specimen was strained to 1% at 0.2%/SEC and held at this level while a strip chart recorder tracked the load response. An X-Y recorder was also employed to track the initial stress-strain response on loading.

## RESULTS & DISCUSSION

Before presenting the stress relaxation results, a short summary of tensile and creep data for CH98 is warranted. Previous testing has shown tensile and creep properties of stabilized and aged CH98 is improved by the additions of tungsten and niobium (Ref. 2). At 1300°F, the yield strength and ultimate strength increase by about 10KSI without adversely affecting ductility as seen in Table 2. The time to 0.2% creep at 1300°F/90KSI, an important design consideration for disk operation, is reproduced in Figure 2. A significant difference in creep resistance is evident, with CH98+WNb showing about 400 hours to 0.2% creep compared to about 100 hours for CH98. The enhanced creep resistance of CH98 with tungsten and niobium additions for stabilized material is especially significant provided the level of stress relief is equivalent to that for CH98. The relative merit of a given stabilization treatment can be assessed by comparing the stress relaxation behavior of the two alloys.

As previously stated, relaxation specimens were first strained to 1%. This produced about 0.5% plastic strain in all tests. The initial stress-strain response of both alloys at 1400°F is presented in Figure 3. The higher strength level produced by tungsten and niobium additions is clearly evident. A comparison of each alloy's relaxation rate, at various temperatures, is shown in Figure 4. Examination of the data shows the relaxation rates of CH98 with and without tungsten and niobium additions are essentially equivalent. Further, it would appear that temperatures between 1500°F and 1600°F provided significant stress relief in both alloys. As a 1550°F/2HR stabilization heat treatment was employed on material used to generate mechanical property data in Ref. 2, duplicate stress relaxation runs were performed on both alloys at 1550°F. The relaxation data, shown in Figure 5, gives some feel for variability between runs and suggests that peak residual stress levels would be no greater than 50 or 60 KSI after stabilization, even for disks given a severe quench after solutioning. Increasing stabilization time beyond two hours and/or increasing stabilization temperature yields additional stress relief, but this benefit must be weighed against losses in tensile strength and creep resistance (Ref. 1).

## CONCLUSIONS

Additions of tungsten and niobium increase the tensile strength and creep resistance of disk alloy CH98 and do not appear to alter the stress relaxation behavior after solution heat treatment. This finding suggests that the benefits of these alloying additions are not compromised by changes to residual stress relief provided by stabilization treatments at 1500°F to 1600°F. Further, stabilization heat treatments in this temperature range would appear to significantly decrease the residual stresses produced by quenching and therefore enhance the machinability of disks.

## REFERENCES

1. Gayda, J., Gabb, T.P. and Ellis, D.L., The Effect of Stabilization Treatments on Disk Alloy CH98, AST023, NASA Report, March 1998.
2. Gayda, J., The Effect of Tungsten and Niobium Additions on Disk Alloy CH98, AST016, NASA Report, August 1997.

**Table 1. Alloy composition in weight percent.**

	Co	Cr	Al	Ti	Mo	Ta	W	Nb	C	B	Zr	Ni
CH98	17.9	11.6	3.90	4.00	2.90	2.90	0.00	0.00	.049	.030	.050	BAL
CH98+WNb	18.3	11.3	3.90	3.80	2.90	2.20	2.30	1.00	.050	.030	.045	BAL

**Table 2. Alloy tensile properties at 1300°F.**

	0.2% YIELD	ULTIMATE	ELONGATION	RED. OF AREA
CH98	123KSI	162KSI	27%	32%
CH98+WNb	136KSI	174KSI	32%	33%

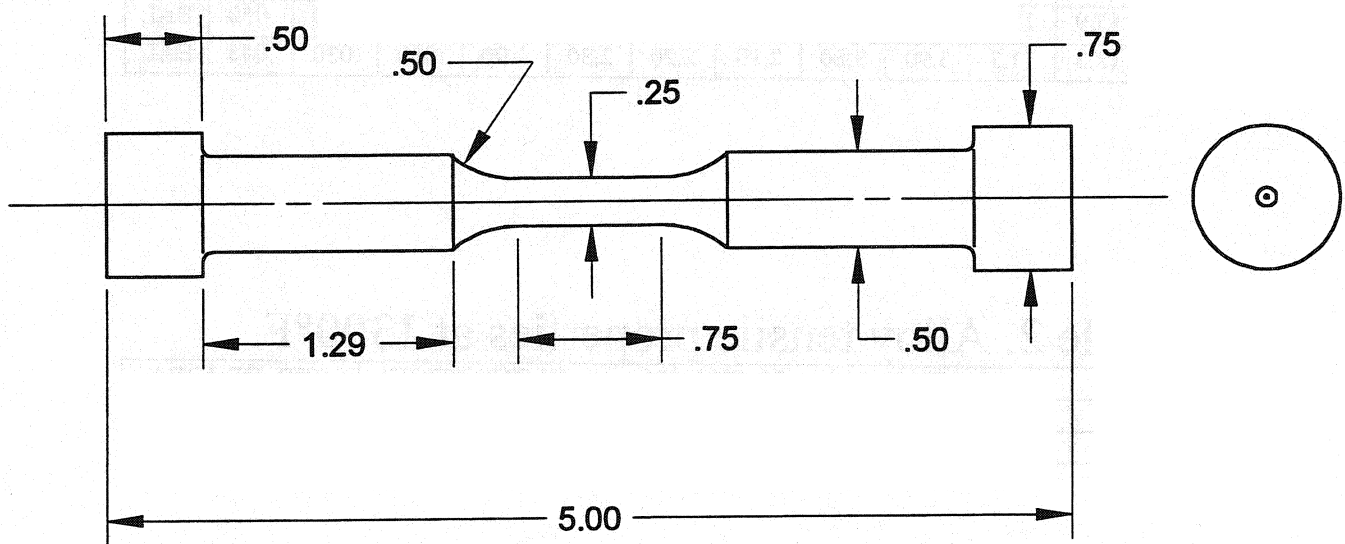
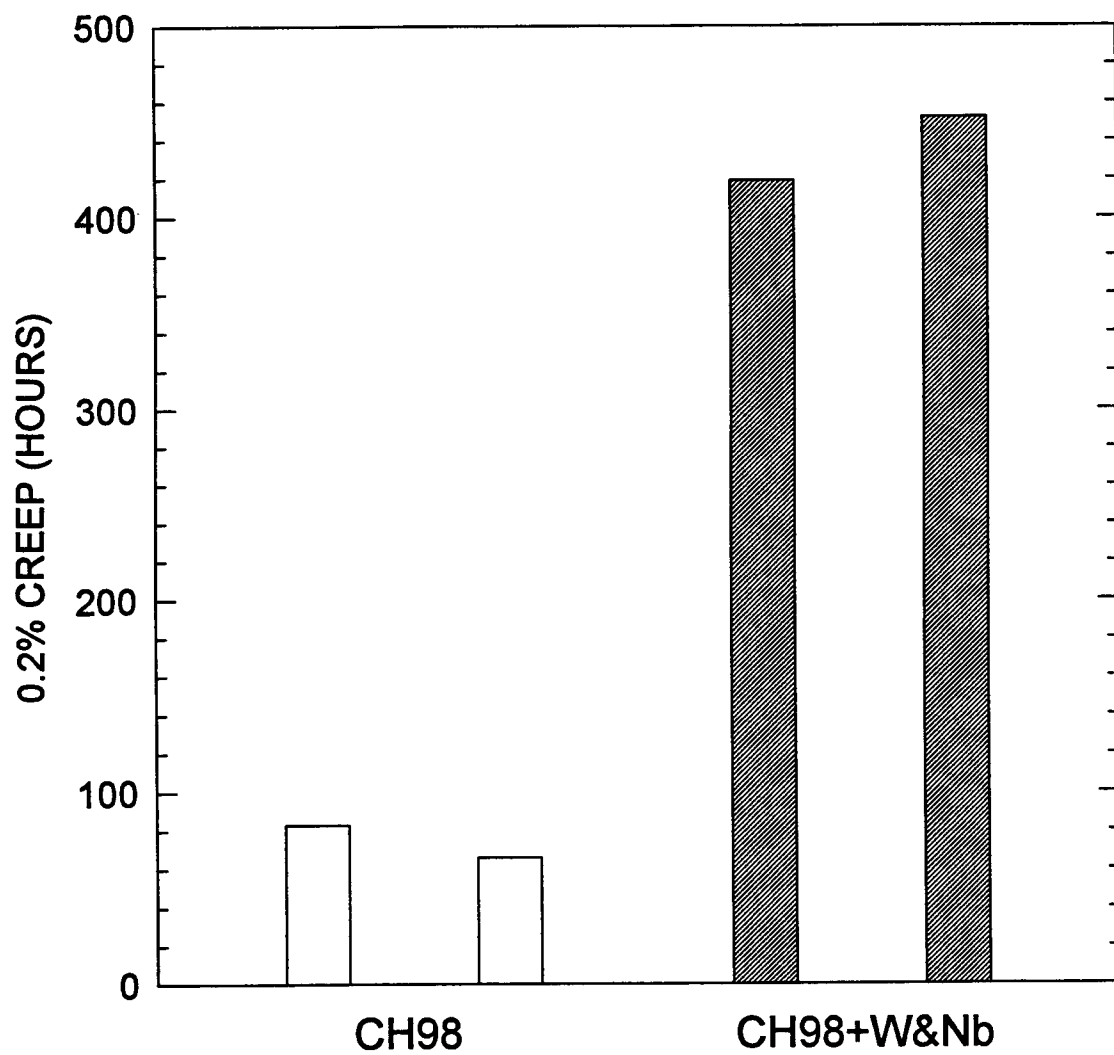
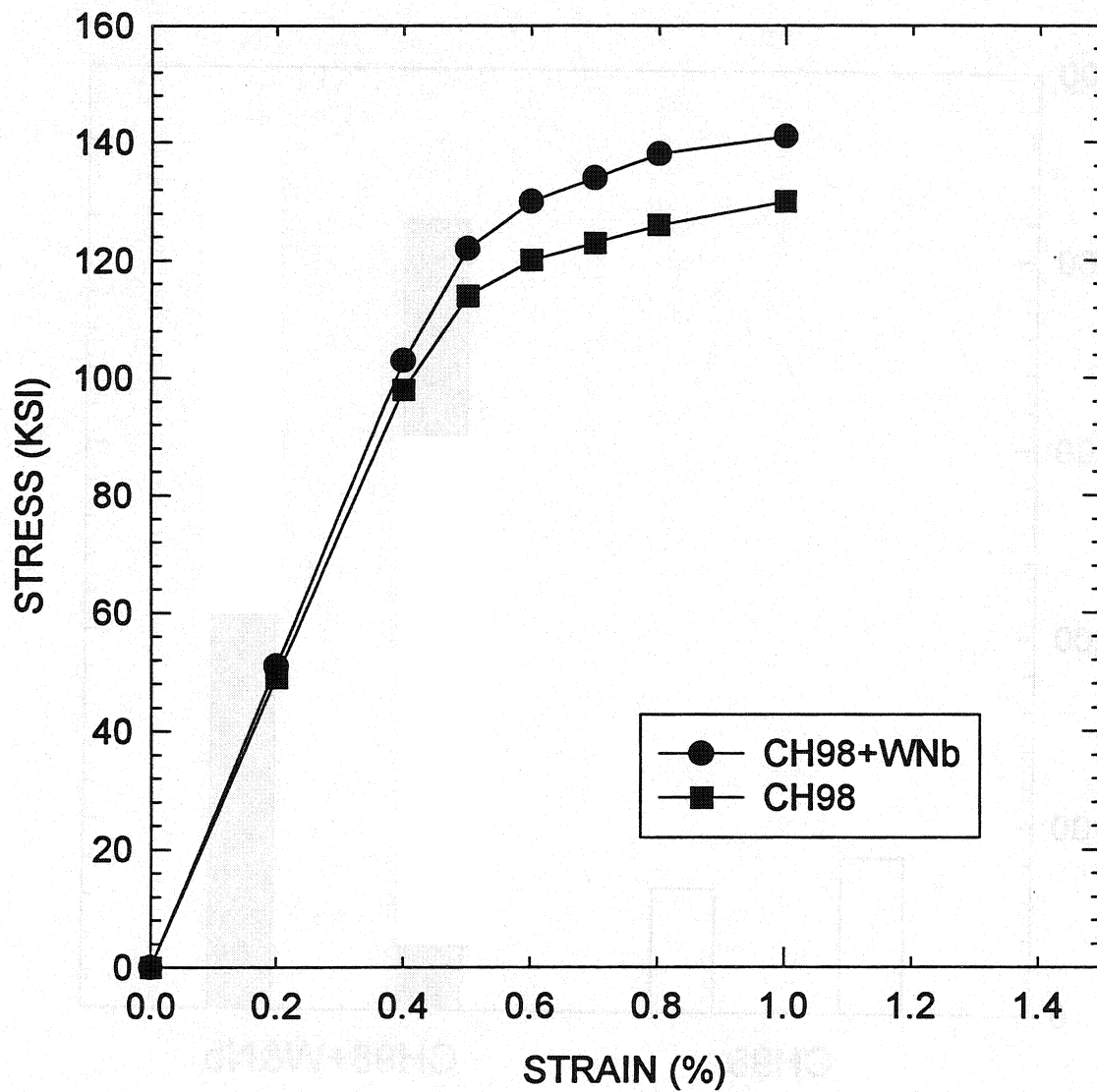


Figure 1. Design of test specimen. All dimensions in inches.

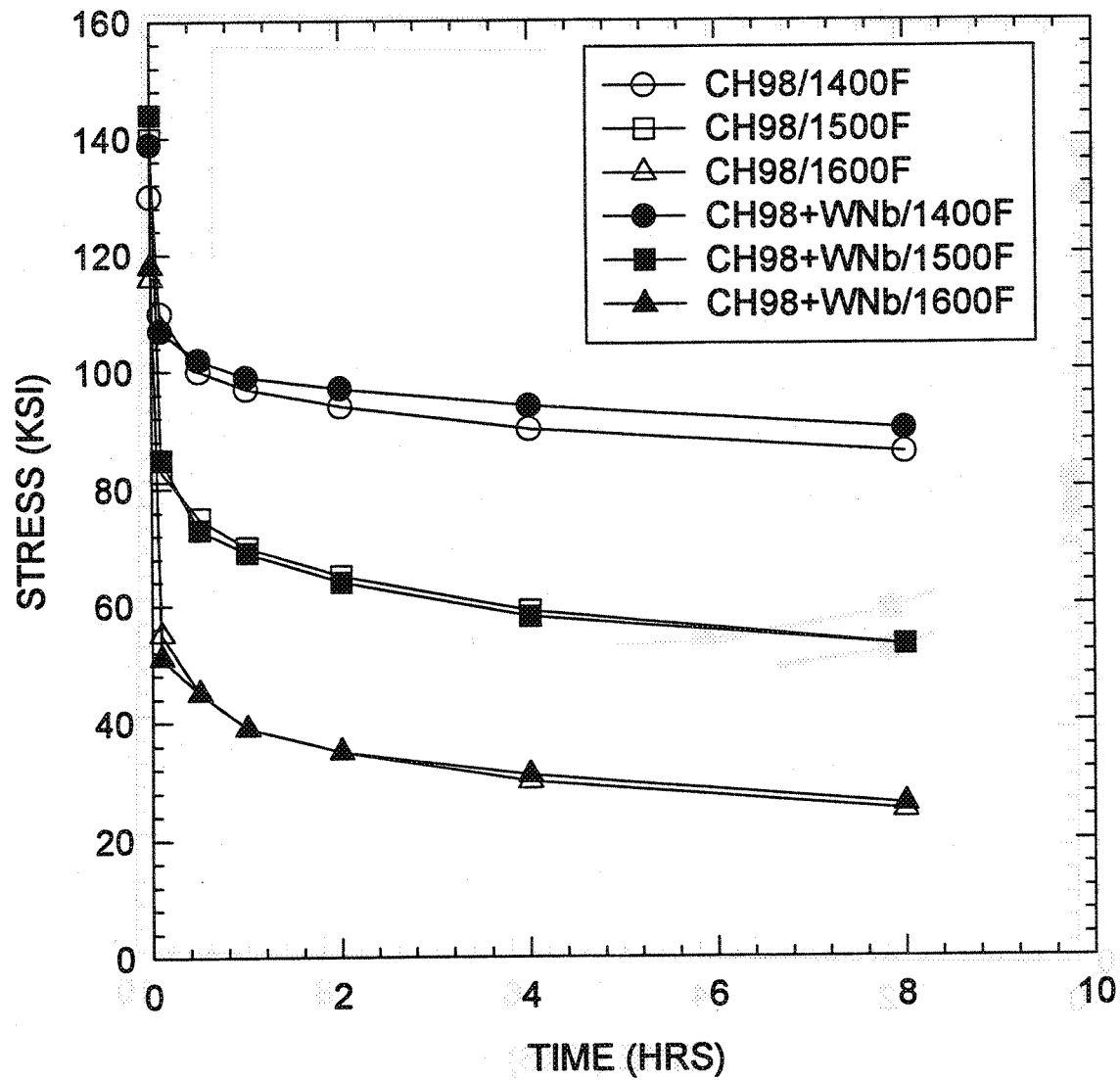




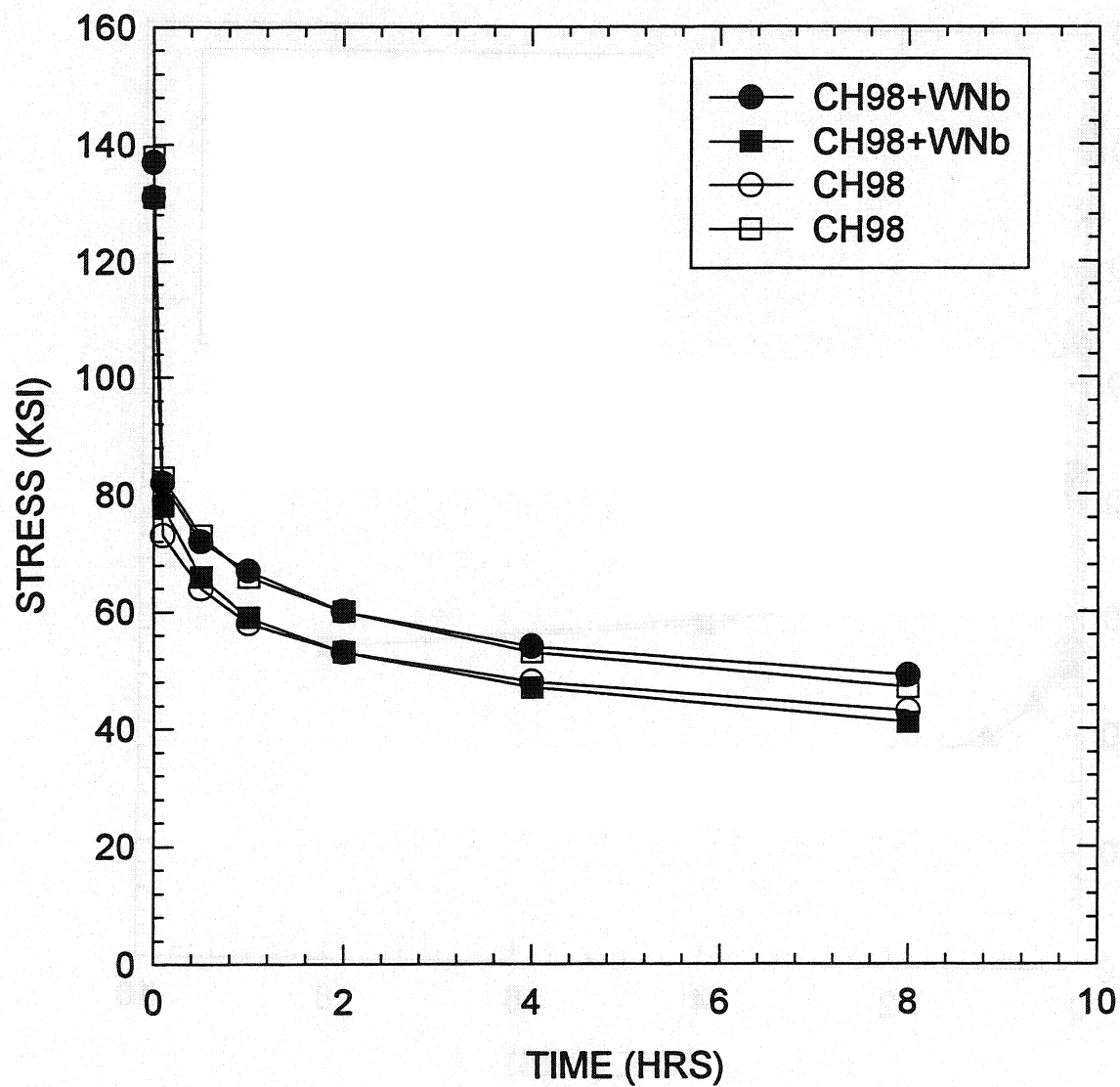
**Figure 2. Comparison of 1300F/90KSI creep data for stabilized and aged CH98 with and without tungsten and niobium.**



**Figure 3. Initial stress-strain response at 1400F.**



**Figure 4. Stress relaxation data as a function of temperature.**



**Figure 5. Stress relaxation data at 1550F.**

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